M E M O R A N D U M

TO: Jayantha Obeysekera, Department Director
Office of Modeling

Luis Cadavid, Sr. Supervising Engineer
Regional Systems Modeling Division, Office of Modeling

FROM: Walter Wilcox, Staff Hydrologic Modeler
Regional Systems Modeling Division, Office of Modeling

Ken Konyha, Lead Engineer
Office of Modeling

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SUBJECT: **Calibration of the Caloosahatchee (C43) Basin AFSIRS/WATBAL model for use in modeling select Lake Okeechobee Service Area basins in V5.0 of the South Florida Water Management Model**

Introduction:

Recent improvements in V5.0 of the SFWMM (Wilcox 2003) allow a consistent modeling approach to estimate demands and runoff in all non-gridded portions of the SFMWW. The AFSIRS/WATBAL model is an appropriate tool for this task. The AFSIRS/WATBAL hydrologic model was developed for the Caloosahatchee Water Management Plan (CWMP) to estimate basin-scale current and future water demand and runoff. Output from this tool has been used in V3.7 and later of the South Florida Water Management Model (SFWMM) for the purpose of modeling selected basins not located within the 2x2 mile gridded portion of the regional model extent. The current version (3.0) of AFSIRS/WATBAL has a high level of automation and substantially faster development and simulation times. The model has been recalibrated to recently updated historical climate, land use and flow data. This memo will review the following topics: 1) brief overview of AFSIRS/WATBAL model including recent improvements; 2) C43 AFSIRS/WATBAL conceptualization and data collection 3) model calibration results.

AFSIRS/WATBAL Model Overview:

The AFSIRS/WATBAL hydrologic model is a basin scale, simple water budget model based on the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) model (Smajstrla, 1990). All major components of the hydrologic cycle are determined in AFSIRS/WATBAL: demands from ground water and surface waters, demands for the major irrigated and nonirrigated land uses, and runoff from ground water irrigated, surface water irrigated and nonirrigated lands. The water budget modeling for a given basin has three primary separate components (Figure 1.1): AFSIRS, AFSIRS Water Budget and WATBAL, as well as a central location for common data (RF_PET_LU_inputs). AFSIRS calculates irrigation requirements for cropland. The AFSIRS Water Budget spreadsheet was developed to calculate and route runoff and ground water components for AFSIRS. The WATBAL spreadsheet calculates the hydrology of nonirrigated land. Further details related to each of these components is available in the appendix to the

CWMP (SFWMD 2000). Depending on whether the model is applied as a single basin implementation or a multiple basin implementation, additional complexity can be added in the form of additional spreadsheets to control the routing from one basin to another.

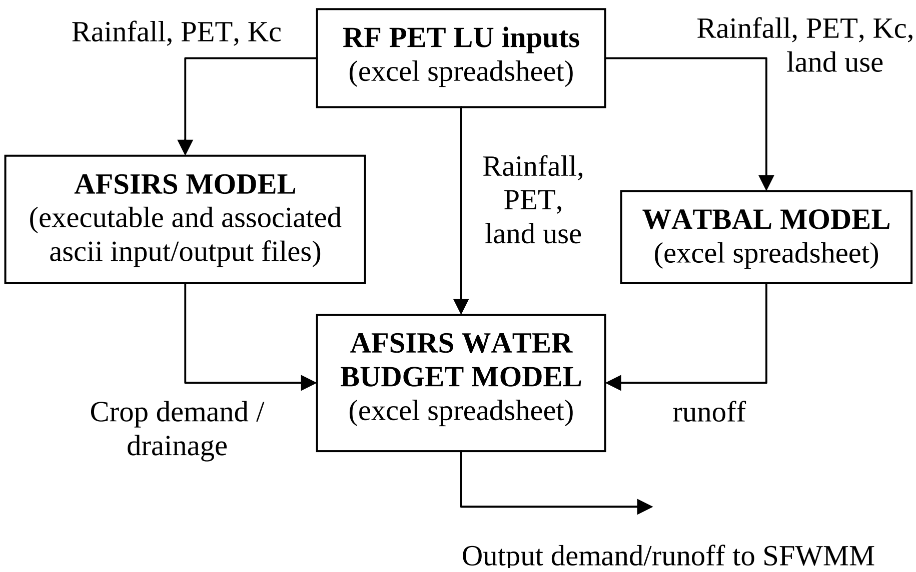

Figure 1.1 – Single Basin Implementation of AFSIRS/WATBAL

In order to run AFSIRS/WATBAL V 3.0, a user must have access to a Windows environment with an installed version on Microsoft Excel (Office 1997 or later) and up to several hundred megabytes of free disk space (depending on the number of basins, approx. 60 MB per basin). The model is located within a single user-specified directory and contains a "READ_ME.txt" file that provides step-by-step instructions to users on the process for making a model run. This process can be described as "partially" automated since some manual work is involved in opening spreadsheets and executing macros. In general, run times should be fast (approx. 2 minutes for a 36 year single basin model simulation on a 1 GHz PC), but performance will depend heavily on system capabilities and the number of basins included in the analysis.

C43 AFSIRS/WATBAL Model – Conceptualization and Data Collection:

V5.0 of the SFWMM requires demand/runoff time series input for (among others) the Caloosahatchee (C43), St. Lucie (C44), S4, Lower Istokpoga, and North/Northeast Lake Shore basins. These basins are geographically close to each other, falling within the Lake Okeechobee Service Area (LOSA). Additionally, they share common land use types (predominantly agriculture or natural systems) and land management practices. A review of available data for these basin indicated that the C43 basin has the most reliable and up-to-date flow information. As such, the decision was made to calibrate an implementation of the AFSISRS/WATBAL model for the C43 basin for the period 1991-2000. Parameters derived from the C43 calibration are then used in modeling all other LOSA basins for regional modeling purposes.

The Caloosahatchee implementation of the AFSIRS/WATBAL model is conceptualized as a four basin model covering the lands between S-77/S-235 and S-79 that influence the regional system. These basins are defined as East Caloosahatchee-ground water irrigated (ecal-gw), East Caloosahatchee-C43 irrigated (ecal-d), West Caloosahatchee-ground water irrigated (wcal-gw), and West Caloosahatchee-C43 irrigated (wcal-d). The break between the "East" and "West" basins is considered to occur at S-78. As previously mentioned, the multi-basin conceptualization of the model requires the addition of spreadsheets to handle the routing between basins. In addition to this need, the C43 basin has the supplementary consideration of public water supply withdrawals from the C43 canal (Lee County and Ft Meyers) and deliveries from the regional system (Lake Okeechobee, C43 reservoir, ASR, etc…) to supplement agricultural and public water supply withdrawals. The final model conceptualization (accounting for all of these considerations) is presented in Figure 2.1.

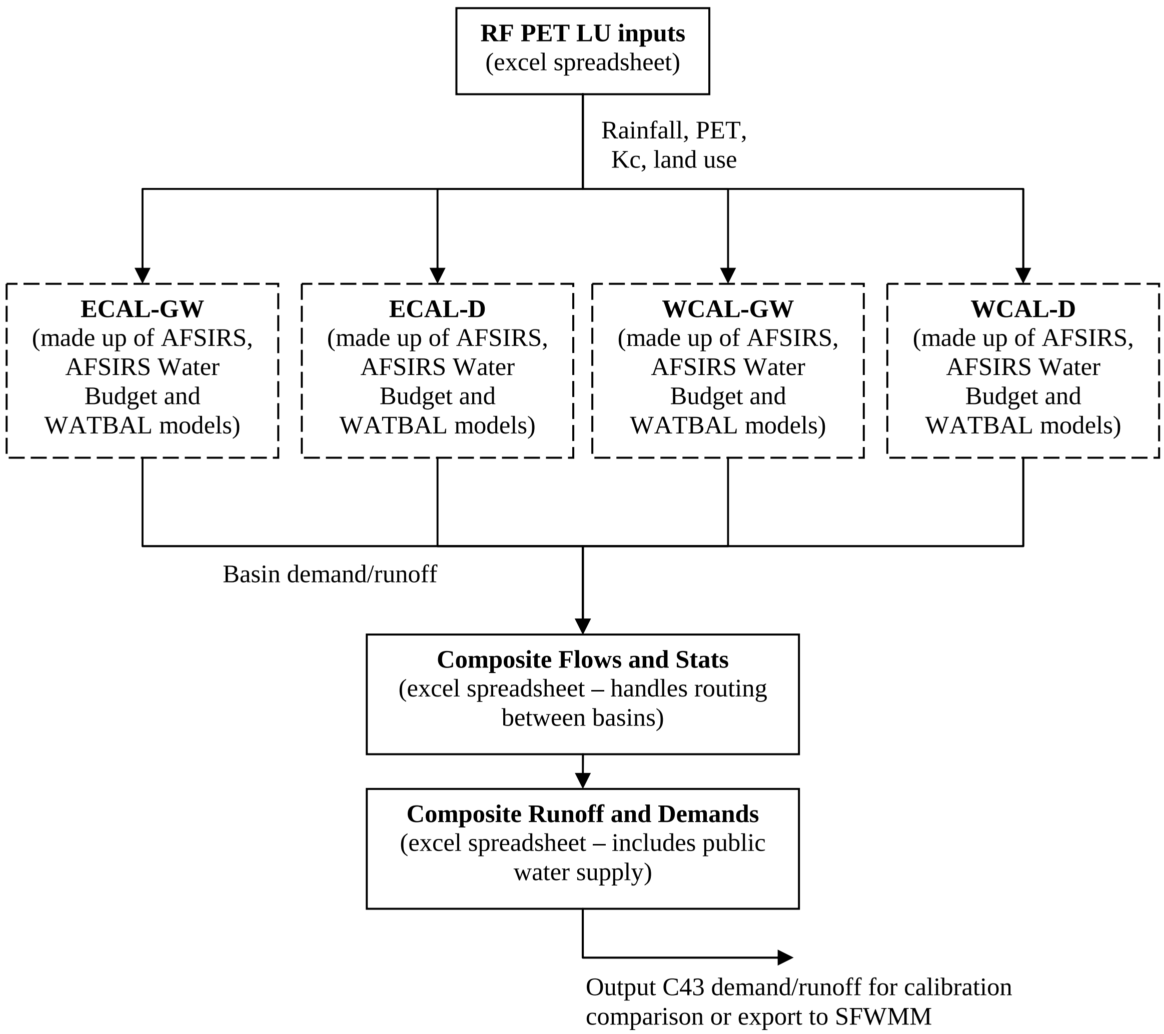

Figure 2.1 – Caloosahatchee (C43) Basin Implementation of AFSIRS/WATBAL

Data for use in the C43 AFSIRS/WATBAL model comes from a wide variety of sources. Climate data was taken from available rainfall (Ali 2003) and potential evapo-transpiration (PET) (Irizarry 2003) data sets created for the SFWMM. Monthly rainfall and PET data are included as attachments to this document. Historical flow data for boundary structures (S-77, S235 and S-79) was obtained from the CERP “modeling” p-dbkeys on the SFWMD’s DBHYDRO database. There was a substantial increase in irrigated lands within the Caloosahatchee over the calibration period. AFSIRS/WATBAL modeling is able to simulate the changes in irrigation demands and runoff that result from changing land uses. For calibration, historic land use-over-time tables were developed for each irrigation basin. District land use coverages were used to establish 1988 (SFWMD 1994), 1995 and 2000 (SFWMD 2002) land use. Land use for intermediate years was interpolated based on historic countywide crop land use data published by Florida Agricultural Statistics Service (FASS).

AFSIRS/WATBAL Model Calibration Results[1]:

The process for calibration of the AFSIRS/WATBAL model is iterative and consists of several steps. Parameters for calibration of the model include two global irrigation parameters, five parameters each for three types of nonirrigated lands and monthly Kc parameters for evapotranspiration estimation for each land use type. The calibration strategy is to select reasonable values for each parameter, run the model, and evaluate the results using several goodness-of-fit (GOF) measures. The GOFs were used to compare the simulated demand and runoff to the measured flows over the calibration period of 1991-2000. Model parameters were adjusted after each run for a subsequent attempt to obtain the best GOFs. An additional check is required after each iteration to ensure that in addition to appropriate basin-scale results, the individual land use performances were also realistic (e.g. no crop had 70" of ET demand, rangeland did not flood to 5', etc.).

The final results of the iterative process yielded calibrated parameters as shown in Tables 3.1, 3.2 and 3.3. Calibration summaries and GOF analysis of agricultural demands are presented in Table 3.4 and Figures 3.1 to 3.3. Results of calibration and GOF analysis of watershed runoff are presented in Table 3.5 and Figures 3.4 to 3.6. Table 3.6 relates the individual water budget summaries for each of the calibrated landuse types for a representative sub-basin (ECAL-D).

In general, the results of the calibration are extremely good, especially considering the amount of uncertainty associated with climate, flow and landuse data estimation. Correlations of modeled to measured data are high for both demand and runoff estimation. In addition, the model calibration shows very little bias and is able to reproduce the seasonal variability observed in the measured data. Additionally, the performances of the individual landuse types, as presented in Table 3.6, are within the expected ranges of behavior. Additional, more specific, comments related to the calibration results are presented in bullet form below.

- The value for EFF1of less than 100% in Table 3.1 indicates that there exists water use within the basin not directly related to crop irrigation requirements. This extra demand (resulting from transmission losses, incidental irrigation, etc.) ends up in the atmosphere but the processes are not modeled.
- The local storage term (STOR1) presented in Table 3.1 is approximately 0.10 inches which represents a small (approximately 6 inch) water table variation
- Kc values as derived in Table 3.3 are intended to be used in conjunction with wet marsh PET estimations by the simplified temperature based method as used in the SFWMM (Irizarry, 2003). These Kc values were capped at a maximum value of 1.10 for open water as is consistent with the assumption in the SFWMM. [Recalibration would be needed if PET estimates are derived using a different method.]
- AFSIRS/WATBAL is a hydrologic, not a hydraulic model and should not be used to estimate peak runoff rates. However, it can predict total storm runoff and GOF measures for runoff are calculated on five-day moving average daily value.

[1] *Results of the C43 calibration of the AFSISRS/WATBAL model as well as supplemental support information and input data have been archived in the SFWMM compact disk repository on "CD-SFWMM-091003-1".*

- Since evaluation of demand estimates is tied in to regulatory (1 in 10 monthly) or more long term time steps, GOF measures for demand are presented on a monthly basis.
- The cumulative demand and runoff traces in Figures 3.3 and 3.6 indicate that modeled demand and runoff follow the same pattern as measured data over the period of record. While the model tends to slightly under-predict demand in earlier years and then over-predict in later years, this is most likely due to inaccurate growth estimate in the landuse data.

Based on the results of the success of the C-43 calibration exercise, it is appropriate to apply the AFSIRS/WATBAL V3.0 model with the C-43 calibrated parameters to all LOSA basins in regional modeling efforts.

Table 3.1 - Calibrated Values for AFSIRS Water Budget Model Parameters

Irrigation efficiency1 (consumptive use by plant / amount lost to air) [EFF1]	87%
Local Storage Depth (inches) [STOR1]	0.10
Drainage capacity (inches/day) [CAP1]	7.00
Storage coefficient (day) [COEF1]	7

Table 3.2 - Calibrated Values for WATBAL Model Parameters

	Rangeland	Upland Forest	Wetlands
Plant available water (PAW) capacity (inches)	0.80	1.60	2.20
Drainable storage capacity (inches) [CAP1]	7.00	7.00	1.00
Storage coefficient (days) [COEF1]	7	7	8
Total ground water storage (inches)	7.00	7.00	5.00
Root zone depth (inches)	11.43	22.86	5.50

Table 3.3 - Calibrated Values for Monthly PET Correction Factors (Kc)

month	citrus	cane	veg	pasture	up forest	wetlands
1	0.71	0.61	0.28	0.54	0.58	0.67
2	0.66	0.57	0.25	0.55	0.59	0.63
3	0.61	0.51	0.87	0.55	0.59	0.57
4	0.64	0.59	0.58	0.75	0.68	0.65
5	0.87	0.88	0.87	0.89	0.89	0.93
6	0.98	0.98	0.96	0.99	1.04	1.04
7	1.02	1.07	1.00	1.03	1.08	1.10
8	0.83	0.90	0.89	0.88	0.93	0.96
9	0.93	1.00	0.29	0.91	0.96	1.06
10	0.99	1.00	0.32	0.83	0.82	1.06
11	0.84	0.80	0.99	0.60	0.70	0.85
12	0.82	0.72	0.63	0.53	0.57	0.77

Table 3.4 - Measures of Goodness of Fit for Calibration of AFSIRS Water Budget Model

Average Annual Demand	
Demand – Modeled	86,407 ac-ft/yr
Demand – Measured	84,367 ac-ft/yr
Goodness of Fit	
Model-Measured Error	2040 ac-ft/yr
Demand (Model)- Demand (Measured) / Demand (Model)	2.36%
Slope of Modeled - Measured Demand	0.962
Regression Coefficient of Modeled - Measured Demand	0.813
Pearson Correlation Coefficient	0.902
Modeled Bias	-170 ac-ft
Root Mean Squared Error	4007 ac-ft

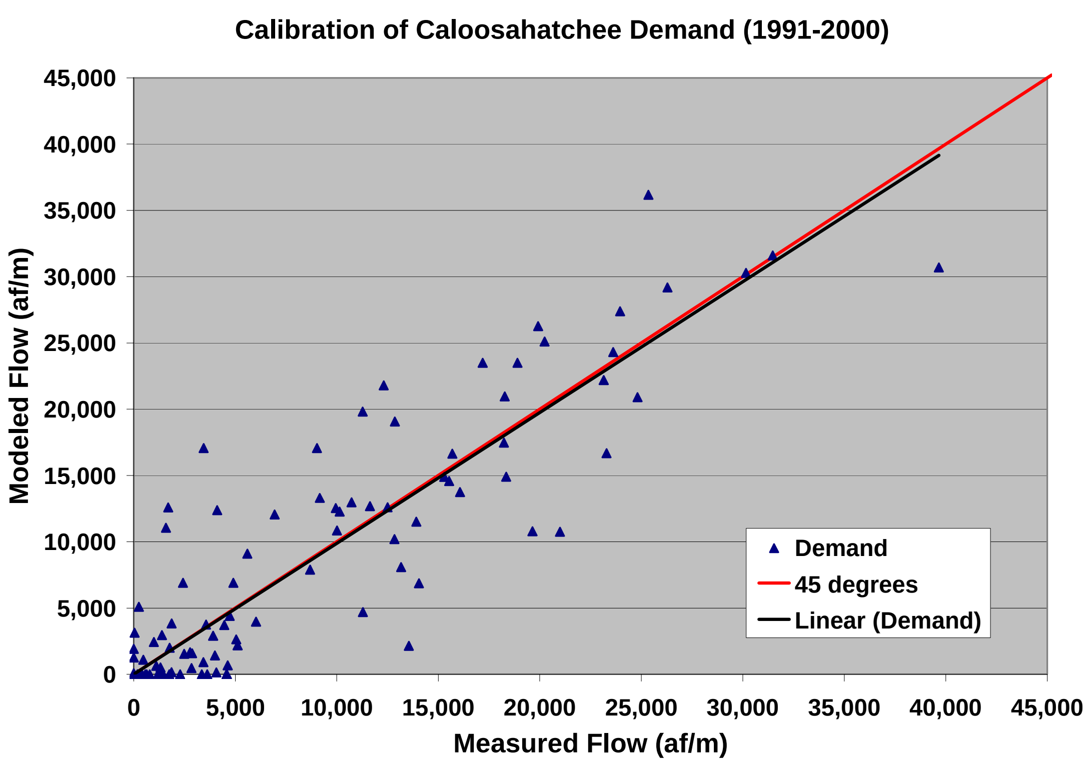

Figure 3.1 –Measured vs. Modeled Caloosahatchee Demand

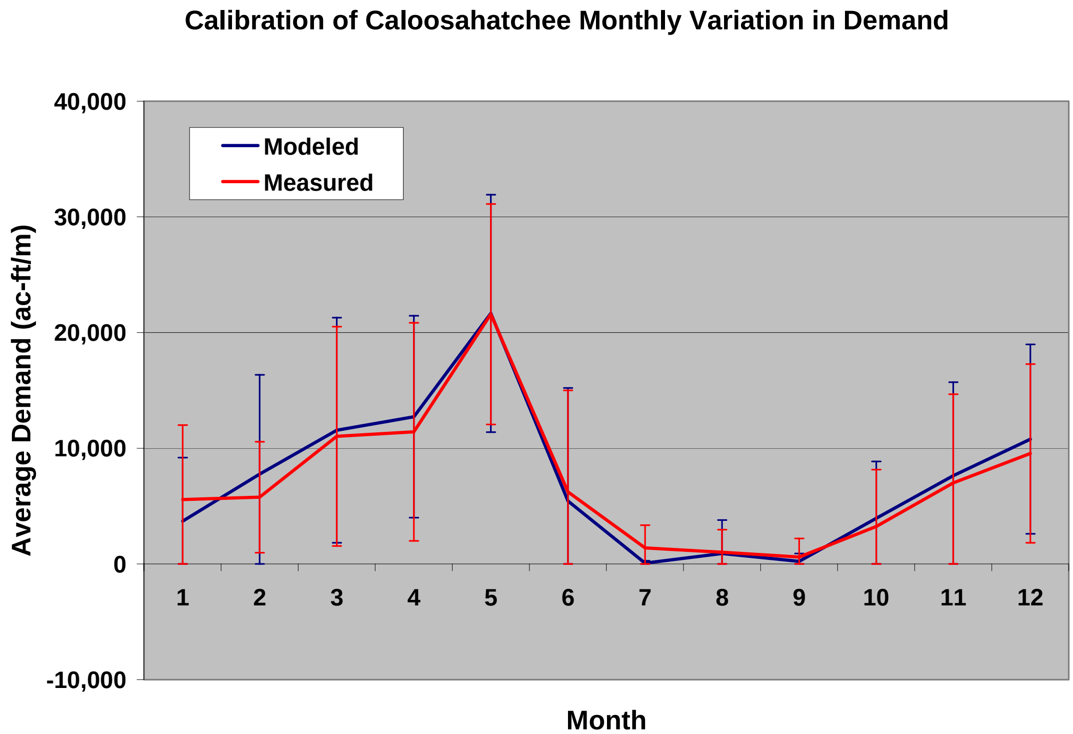

Figure 3.2 –Seasonal Variability in Caloosahatchee Demand

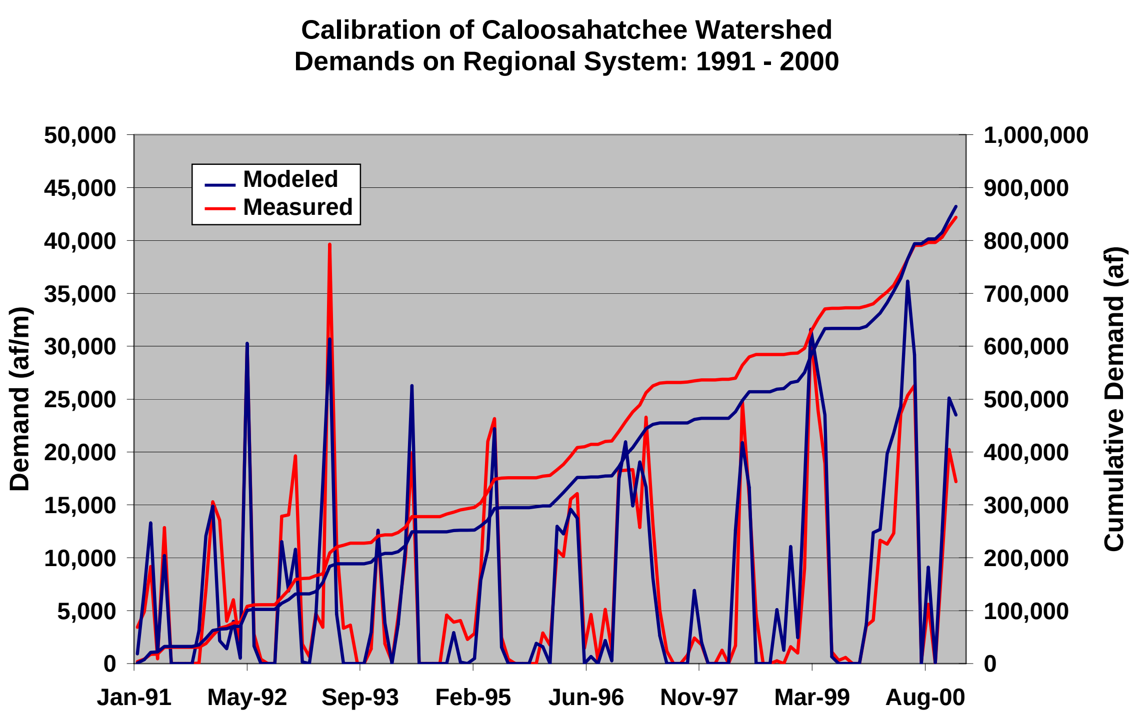

Figure 3.3 –Time Series of Monthly Caloosahatchee Demand and Accumulation

Table 3.5 - Measures of Goodness of Fit for Calibration of WATBAL Model

Average Annual Runoff	
Runoff - Modeled	803,863 ac-ft/yr
Runoff - Measured	799,598 ac-ft/yr
Goodness of Fit	
Model-Measured Error	4,265 ac-ft/yr
Runoff (Model)- Runoff (Measured) / Runoff (Model)	0.53%
Slope of Modeled - Measured Runoff	0.973
Regression Coefficient of Modeled - Measured Runoff	0.825
Pearson Correlation Coefficient	0.908
Modeled Bias	12 ac-ft
Root Mean Squared Error	1477 ac-ft

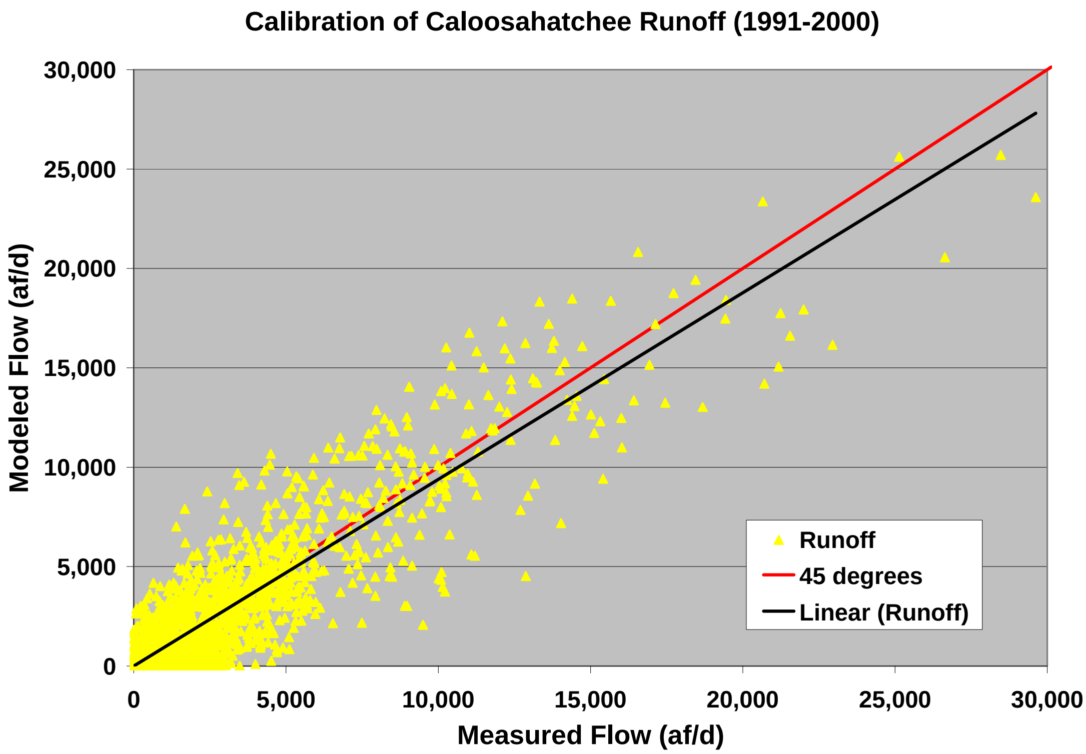

Figure 3.4 –Measured vs. Modeled Caloosahatchee Runoff

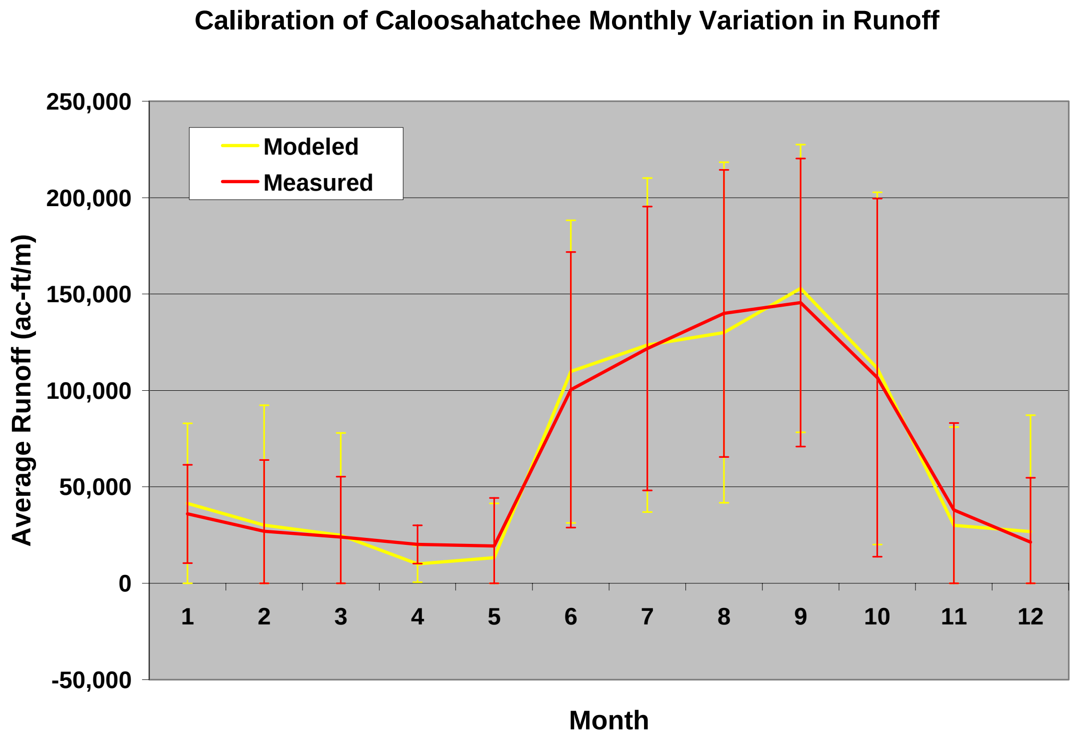

Figure 3.5 –Seasonal Variability in Caloosahatchee Runoff

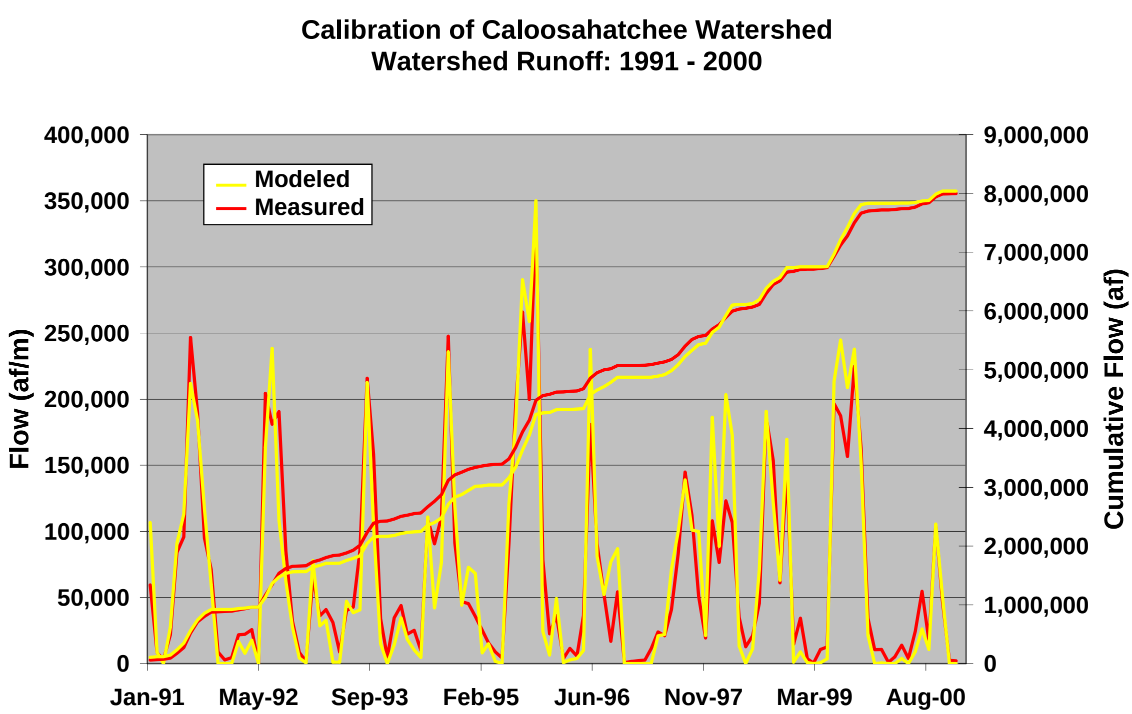

Figure 3.6 –Time Series of Monthly Caloosahatchee Runoff and Accumulation

Table 3.6 - Water Budget Summaries for Calibrated Landuse Types (ECAL-D sub-basin)

	Landuse						
	Citrus - crownflood irrigated	Citrus - microjet irrigated	Sugarcane - subseepage irrigated	Tomatoes – microspray irrigated	Range -land	Upland Forest	Wetland
Rain (in/yr)	50.6	50.6	50.6	50.6	50.6	50.6	50.6
Actual Evapo-transpiration (in/yr)	48.8	48.7	47.9	45.2	34.2	37.5	40.6
AFSIRS Irrigation (in/yr)	15.9	6.8	16.9	10.4	-	-	-
AFSIRS Runoff (in/yr)	17.7	8.7	19.6	15.8	-	-	-
Drainage and Recharge (in/y)	-	-	-	-	16.4	13.1	10.0
Maximum Flooding Depth (in)	-	-	-	-	0.0	2.4	9.9

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Attachment 1 – Monthly Rainfall (in) for C43 Basin as V3.0 AFSIRS/WATBAL Modeled

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1965	0.55	3.18	3.53	2.03	1.95	11.66	9.09	8.59	5.99	5.87	0.38	1.22
1966	3.29	2.47	0.66	3.20	4.82	11.55	7.10	8.37	8.03	2.39	0.20	0.84
1967	1.58	2.94	0.34	0.06	1.89	11.88	7.54	5.99	6.28	3.56	0.35	2.13
1968	0.39	1.97	1.08	0.91	8.41	12.27	8.66	5.55	4.71	4.91	2.61	0.16
1969	1.74	1.68	5.74	1.01	4.10	9.91	4.95	6.96	6.55	7.95	0.86	3.09
1970	4.26	2.20	14.50	0.16	6.18	7.19	7.38	4.61	5.75	3.62	0.28	0.29
1971	0.46	1.11	0.28	0.69	4.14	10.85	7.20	7.63	6.57	5.26	1.15	0.90
1972	0.82	2.25	3.09	1.68	2.91	10.18	4.75	6.94	2.71	1.31	4.72	1.48
1973	3.39	2.97	4.21	1.32	2.87	7.69	10.51	9.14	6.23	2.26	0.48	1.73
1974	0.15	1.01	0.28	1.14	5.33	16.22	12.51	7.62	6.29	0.61	2.02	1.22
1975	0.21	0.99	0.90	2.64	7.12	8.00	8.03	5.87	8.58	4.27	0.31	0.59
1976	0.52	1.73	2.15	1.56	7.12	7.22	8.18	6.81	5.87	1.88	2.42	1.68
1977	4.31	0.77	0.34	0.35	4.14	5.25	7.15	7.53	7.31	1.10	2.67	3.62
1978	2.35	2.04	3.43	1.75	5.01	8.20	10.10	6.86	5.57	2.89	1.55	4.53
1979	5.90	0.57	1.73	2.43	7.31	4.54	4.96	6.26	13.25	1.43	2.06	2.88
1980	2.74	1.43	2.48	4.13	3.02	1.99	8.47	7.74	4.73	1.19	3.16	0.53
1981	0.80	1.69	1.46	0.20	2.40	6.39	5.75	10.35	4.01	0.56	2.14	0.30
1982	0.73	2.24	4.39	3.18	9.41	14.41	8.71	5.76	6.50	5.41	0.50	0.64
1983	4.21	10.36	6.27	1.73	0.99	11.91	5.01	6.91	6.34	5.70	2.16	3.55
1984	0.34	3.20	4.97	2.74	6.85	6.91	9.69	4.48	4.94	0.62	3.22	0.30
1985	0.51	0.48	1.79	4.29	2.68	7.50	7.38	7.09	8.23	2.58	1.63	1.56
1986	1.96	1.55	5.20	0.25	1.43	13.04	6.73	8.37	4.55	5.33	0.33	4.40
1987	2.24	2.48	7.15	0.38	4.13	5.42	6.99	4.51	7.85	6.33	8.76	0.33
1988	2.10	2.28	3.56	1.84	2.87	4.19	7.67	10.34	2.33	0.86	4.60	1.18
1989	1.24	0.39	3.59	4.48	1.58	8.74	8.11	7.59	6.40	4.12	0.39	1.95
1990	0.75	2.44	1.29	2.29	3.10	7.44	8.02	10.66	3.88	2.69	0.53	0.15
1991	6.28	1.24	2.24	4.27	8.55	8.37	11.45	7.37	5.22	3.47	1.78	0.19
1992	2.13	3.79	3.13	3.81	1.33	17.32	4.38	8.23	4.60	1.29	2.05	0.75
1993	5.85	2.13	2.84	2.02	2.05	6.61	6.97	7.90	6.43	6.24	0.95	0.89
1994	3.58	3.02	2.47	4.02	3.62	7.76	6.62	7.25	10.13	3.94	2.95	4.42
1995	3.43	1.74	2.56	3.24	2.13	10.60	13.00	10.93	7.04	11.48	0.47	0.45
1996	3.24	0.98	3.87	1.52	6.46	12.27	4.62	8.54	3.74	5.31	0.57	0.55
1997	0.98	0.90	2.01	6.33	4.61	8.14	9.81	6.75	9.30	0.91	4.54	6.64
1998	2.78	7.79	5.80	1.13	3.39	4.23	8.05	9.95	8.14	2.68	6.24	0.97
1999	3.11	0.19	0.64	2.47	4.26	17.12	6.00	11.64	9.08	4.82	1.04	1.00
2000	1.18	0.33	1.77	2.32	1.61	5.89	5.67	4.77	8.44	1.89	0.24	0.47

Attachment 2 – Monthly PET (in) for C43 Basin as V3.0 AFSIRS/WATBAL Modeled

Year	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1965	3.68	3.84	5.00	5.78	6.54	5.54	5.62	5.33	4.26	3.83	3.32	3.28
1966	3.32	3.64	4.96	5.59	5.92	5.15	5.32	5.30	4.40	3.83	3.50	3.43
1967	3.53	3.92	5.10	6.06	6.60	5.81	5.63	5.36	4.62	3.94	3.56	3.28
1968	3.62	4.14	5.48	6.00	5.86	5.14	5.43	5.27	4.51	3.92	3.54	3.45
1969	3.54	3.97	4.78	5.44	5.82	5.55	5.70	5.42	4.39	3.62	3.48	3.50
1970	3.42	3.89	4.61	5.55	6.06	5.83	5.96	5.55	4.71	4.20	3.88	3.69
1971	3.86	4.06	5.73	6.28	6.83	6.37	6.12	5.60	4.56	4.21	3.35	3.24
1972	3.64	4.13	5.56	6.00	6.49	5.53	5.87	5.74	4.80	4.37	3.44	3.34
1973	3.55	3.92	5.25	5.93	6.63	6.00	5.86	5.17	4.29	3.79	3.49	3.44
1974	3.56	4.21	5.49	6.09	6.50	5.79	5.72	5.37	4.64	4.10	3.39	3.32
1975	3.53	4.04	5.53	6.06	6.31	5.94	5.87	5.52	4.69	4.04	3.44	3.45
1976	3.92	4.19	5.36	5.93	6.08	5.66	6.06	5.45	4.44	4.22	3.42	3.07
1977	3.76	3.99	5.13	5.80	6.21	6.03	6.00	5.33	4.61	4.42	3.52	3.32
1978	3.56	3.78	5.10	5.90	6.13	5.73	5.86	5.51	4.79	4.00	3.38	3.09
1979	3.49	3.97	5.24	5.54	5.89	5.92	5.92	5.56	4.08	4.02	3.22	3.05
1980	3.54	4.05	5.08	5.40	6.19	6.08	5.95	5.36	4.57	4.25	3.22	3.44
1981	4.05	4.03	5.46	5.90	6.91	5.96	6.16	5.09	4.58	4.30	3.76	3.49
1982	3.88	3.95	5.22	5.46	6.15	5.13	5.69	5.25	4.33	3.79	3.21	3.16
1983	3.43	3.43	4.80	5.57	6.29	5.49	5.73	5.27	4.35	3.88	3.29	2.98
1984	3.42	3.87	5.04	5.54	5.85	5.56	5.54	5.35	4.44	4.06	3.36	3.26
1985	3.77	3.94	5.34	5.63	6.47	5.94	5.75	5.43	4.60	4.00	3.29	3.23
1986	3.64	3.96	5.02	6.26	6.38	5.62	5.69	5.17	4.58	4.12	3.10	3.02
1987	3.59	3.72	4.56	5.89	5.86	5.67	5.81	5.51	4.71	4.06	3.09	3.24
1988	3.38	4.03	5.09	5.86	6.18	5.63	5.67	5.33	4.53	4.51	3.35	3.42
1989	3.71	4.05	5.04	5.94	6.51	6.03	5.83	5.44	4.62	4.11	3.54	3.41
1990	3.56	3.78	5.15	5.75	5.72	5.79	5.74	5.53	4.61	4.07	3.62	3.46
1991	3.52	3.98	5.18	5.63	5.76	5.67	5.67	5.33	4.57	3.92	3.49	3.30
1992	3.60	4.08	5.24	5.25	6.41	5.52	5.74	5.29	4.35	3.90	2.91	3.16
1993	3.06	3.75	4.94	5.56	5.82	5.66	5.92	5.59	4.60	3.86	3.26	3.44
1994	3.42	3.95	5.11	5.46	6.23	5.98	5.79	5.37	4.43	4.05	3.17	3.15
1995	3.61	3.77	4.98	5.37	5.96	5.84	5.69	5.32	4.52	3.87	3.45	3.21
1996	3.42	4.01	5.15	5.69	5.91	5.56	5.46	5.29	4.67	4.07	3.47	3.45
1997	3.83	3.99	5.10	5.28	5.91	5.84	5.94	5.39	4.38	3.99	3.44	3.03
1998	3.26	3.64	4.75	5.35	5.91	5.98	5.84	5.33	4.25	4.03	3.30	3.20
1999	3.46	4.02	5.57	6.00	6.49	5.58	5.71	5.18	4.41	3.65	3.19	3.06
2000	3.42	3.89	4.89	5.66	6.01	5.68	5.69	5.39	4.51	4.11	3.52	3.32